

Refractometric Studies of Binary Mixtures of Flavoured Compounds and Some Hydrocarbons

Neetu Yadav^{*a}, Tanvir Arfin^b and S.S. Yadava^a

^aDepartment of Chemistry, DDU Gorakhpur University, Gorakhpur-273009 U.P., India

^bChemical Resource Beneficiation (CRB) Research Focus Area, PGM Group, North-West University, Private Bag X6001, Potchefstroom 2520, South Africa

Abstract: Refractive indices have been measured for the binary liquid mixtures of n-butylethanoate and 3-methylethanoate with cyclohexane, benzene, 1,4-dimethylbenzene and 1,3,5-trimethylbenzene over the entire composition range at 308.15K. From the experimental data, the values of deviation in refractive index (Δn), molar refraction (R) and deviation in molar refraction (ΔR) have been determined. The values of Δn and ΔR have been fitted to the Redlich - Kister polynomial equation to determine the standard deviation.

Keywords: Refractive index, binary liquid mixtures and molar refraction, density.

INTRODUCTION

Physical properties of several esters in their binary mixtures have been already reported [1-8]. However, studies in this regard for the determination of refractive indices of the binary mixtures of n-butylethanoate and 3-methylbutylethanoate at 308.15K are still lacking. Esters are an important class of organic compounds having characteristic fruity odour. They are used as component of perfumes and flavourings. Higher esters have low solubility in water and used as extraction solvents for fine chemicals particularly for certain antibiotics. They are also useful in cosmetics and materials for personal care.

3-methylbutylethanoate is used as solvent for old oil colors, perfuming, shoe polish, metallic paints and in photographic films.

In our laboratory refractive index studies have been made on binary systems of bromoalkanes and cyclohexane and aromatic hydrocarbons. Literature reveals that binary systems of esters and aromatic hydrocarbons have rarely been studied employing refractive index measurements. In view of this, binary systems of flavoured compounds viz. 1-butylethanoate and 3-methylbutylethanoate and aromatic hydrocarbons viz. benzene, 1,4-dimethylbenzene and 1,3,5-trimethylbenzene having successive methylation and differing in the polarisability have been selected in the present investigation. Since cyclohexane has a six membered ring without any Π -electrons, binary mixtures of both the esters with it are also studied at

experimental temperature in order to have a reference point for composition of unlike molecular interactions.

EXPERIMENTAL

1-Butylethanoate (Merck India, 98%), 3-methylbutylethanoate (Merck India, 99%), cyclohexane (Merck India, HPLC grade, 99.7%) benzene (Merck India, 99.7%), 1,4-dimethylbenzene (Merck, Germany, 99%) and 1,3,5-trimethylbenzene (Merck, Germany, 98%) supplied by manufacturers were used. Except HPLC grade cyclohexane, all other chemicals were further purified, before sample preparation, by fractional distillation over one meter long column and only middle fraction of distillates were used.

Binary mixtures were prepared by weight covering whole mole fractions range in a sealed glass vials and component liquids were injected by means of syringe to minimize evaporation losses during sample preparation. Weights were measured employing single pan analytical balance (Model K-15 Deluxe, K. Roy Instruments Pvt. Ltd. Varanasi) with a precision of $\pm 0.00001 \times 10^{-3}$ kg.

Densities of the liquids and their binary mixtures were measured employing stem pycnometer having bulb capacity about 12.0×10^{-6} m³. Liquids in the pycnometer were injected by syringe with about 9.0×10^{-2} m long Lumber puncture needle. Pycnometer containing samples was suspended for half an hour in a water thermostat maintain at constant temperature of 308.15 ± 0.03 K in order to equilibrate the sample temperature. Densities of liquids and their mixtures were determined with an uncertainty of ± 0.0001 kgm⁻³ by taking into account of buoyancy correction [9] as follows:

*Address correspondence to this author at the Department of Chemistry, DDU Gorakhpur University, Gorakhpur-273009 U.P., India; Tel: +91-09621228143; E-mail: uaneetu@gmail.com

$$\rho_t^0(\text{liquid}) = (W'/W) \rho_t^0(\text{water}) + 1.2 [1 - ((W'/W))] \text{kgm}^{-3} \dots (1)$$

where $\rho_t^0(\text{liquid})$ and $\rho_t^0(\text{water})$ are the densities of liquid and water respectively at experimental temperature t . W' and W are weights of liquids and water respectively having same volume in pycnometer at temperature t^0 . 1.2 kgm^{-3} is the density of air. Refractive indices of liquids and their binary mixtures were measured with the help of Abbe Refractometer with an uncertainty of ± 0.0002 (model R-8, MS Advanced Research Instrument Company New Delhi) using white light. Temperature of the sample was kept constant by circulating water from thermostat at

constant experimental temperature with the help of tullu pump through the upper and lower prism boxes of the Abbe Refractometer. The diagram and photograph of the refractometer is shown in Figures 1 and 2 respectively. Measurements of refractive indices were carried out after attainment of constant temperature by the sample. An average of three to four measurements for each sample was taken.

RESULTS AND DISCUSSION

The experimental values of densities and refractive indices at 308.15 K for all the four binary mixtures and

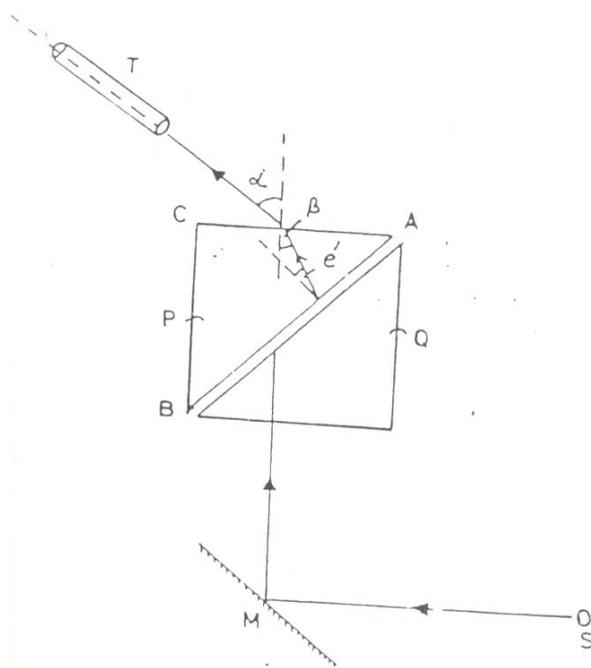


Figure 1: Operating Principle of the Abbe Refractometer.

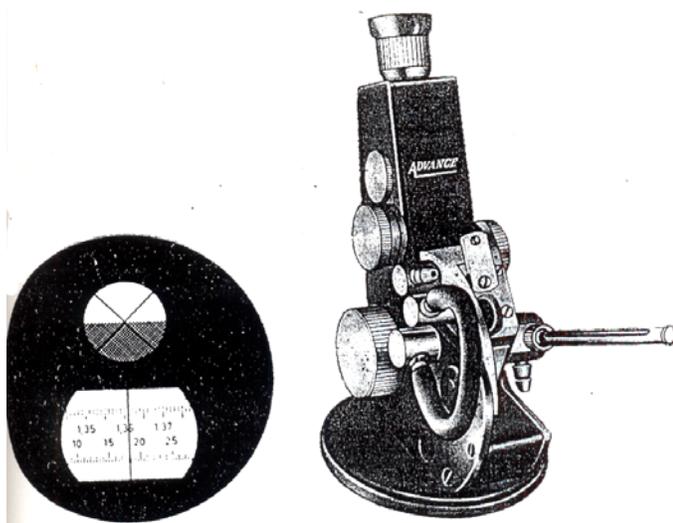


Figure 2: Abbe Refractometer.

Table 1: Mole Fraction of Hydrocarbons (x_1), Refractive Index (n) and Deviations in Refractive Index (Δn), Molar Refraction (R), Deviations in Molar Refractions (ΔR) at 308.15 K for Various Samples of 1-Butylethanoate + Hydrocarbons (x_1) System

| S. No. | x_1 | n | Δn | $R \times 10^6$ ($\text{m}^3 \text{mol}^{-1}$) | $\Delta R \times 10^6$ ($\text{m}^3 \text{mol}^{-1}$) |
|--|---------|--------|------------|---|--|
| 1-Butylethanoate(x_2) + cyclohexane(x_1) | | | | | |
| 1. | 0.00000 | 1.3898 | 0.0000 | 31.8078 | 0.0000 |
| 2. | 0.11657 | 1.3902 | -0.0030 | 31.1770 | -0.2424 |
| 3. | 0.20031 | 1.3912 | -0.0045 | 30.8692 | -0.2562 |
| 4. | 0.31271 | 1.3940 | -0.0050 | 30.4740 | -0.5187 |
| 5. | 0.39690 | 1.3958 | -0.0057 | 30.1264 | -0.2794 |
| 6. | 0.49716 | 1.3984 | -0.0060 | 29.7443 | -0.2737 |
| 7. | 0.60311 | 1.4012 | -0.0063 | 29.3228 | -0.2689 |
| 8. | 0.76467 | 1.4050 | -0.0351 | 29.0649 | -0.1585 |
| 9. | 0.79800 | 1.4088 | -0.0045 | 28.5994 | -0.1601 |
| 10. | 0.89938 | 1.4134 | -0.0028 | 28.1937 | -0.1063 |
| 11. | 1.00000 | 1.4192 | 0.0000 | 27.8246 | 0.0000 |
| 1-Butylethanoate(x_2) + Benzene(x_1) | | | | | |
| 1. | 0.00000 | 1.3898 | 0.0000 | 31.8078 | 0.0000 |
| 2. | 0.09512 | 1.3938 | -0.0057 | 31.1025 | -0.3390 |
| 3. | 0.19675 | 1.4012 | -0.0088 | 30.5463 | -0.4768 |
| 4. | 0.32022 | 1.4098 | -0.0128 | 29.7921 | -0.6813 |
| 5. | 0.40430 | 1.4182 | -0.0130 | 29.4010 | -0.6667 |
| 6. | 0.48964 | 1.4274 | -0.0125 | 29.0120 | -0.6251 |
| 7. | 0.61107 | 1.4382 | -0.0142 | 28.2540 | -0.7062 |
| 8. | 0.70029 | 1.4494 | -0.0121 | 27.8432 | -0.5783 |
| 9. | 0.79976 | 1.4620 | -0.0097 | 27.3105 | -0.4606 |
| 10. | 0.89928 | 1.4768 | -0.0051 | 26.8227 | -0.2313 |
| 11. | 1.00000 | 1.4922 | 0.0000 | 26.2723 | 0.0000 |
| 1-Butylethanoate(x_2) + 1,4-Dimethylbenzene(x_1) | | | | | |
| 1. | 0.00000 | 1.3898 | 0.0000 | 31.8078 | 0.0000 |
| 2. | 0.10178 | 1.3968 | -0.0030 | 32.0748 | -0.1427 |
| 3. | 0.20346 | 1.4062 | -0.0036 | 32.5014 | -0.1311 |
| 4. | 0.29847 | 1.4152 | -0.0040 | 32.8035 | -0.1583 |
| 5. | 0.39370 | 1.4248 | -0.0037 | 33.3763 | -0.0478 |
| 6. | 0.50142 | 1.4352 | -0.0039 | 33.8304 | -0.0518 |
| 7. | 0.60780 | 1.4462 | -0.0034 | 34.3104 | -0.0306 |
| 8. | 0.70528 | 1.4562 | -0.0030 | 34.7380 | -0.0295 |
| 9. | 0.79968 | 1.4664 | -0.0021 | 35.1948 | -0.0097 |
| 10. | 0.89814 | 1.4768 | -0.0014 | 35.6205 | -0.0083 |
| 11. | 1.00000 | 1.4882 | 0.0000 | 36.0933 | 0.0000 |

(Table 1). Continued.

| S. No. | x_1 | n | Δn | $R \times 10^6$ ($m^3 mol^{-1}$) | $\Delta R \times 10^6$ ($m^3 mol^{-1}$) |
|--|---------|--------|------------|---------------------------------------|--|
| 1-Butylethanoate (x_2) + 1,3,5-Trimethylbenzene(x_1) | | | | | |
| 1. | 0.00000 | 1.3898 | 0.0000 | 31.8078 | 0.0000 |
| 2. | 0.09900 | 1.3978 | -0.0020 | 32.5414 | -0.2002 |
| 3. | 0.20156 | 1.4090 | -0.0012 | 33.5233 | -0.1577 |
| 4. | 0.29992 | 1.4194 | -0.0008 | 34.4700 | -0.1383 |
| 5. | 0.41012 | 1.4312 | -0.0002 | 35.5071 | -0.1100 |
| 6. | 0.50516 | 1.4410 | -0.0000 | 36.3733 | -0.1045 |
| 7. | 0.61064 | 1.4500 | -0.0031 | 37.0725 | -0.3706 |
| 8. | 0.70100 | 1.4598 | -0.0011 | 38.0492 | -0.1782 |
| 9. | 0.80266 | 1.4694 | -0.0018 | 38.9134 | -0.2089 |
| 10. | 0.90050 | 1.4770 | -0.0041 | 39.6060 | -0.3429 |
| 11. | 1.00000 | 1.4912 | 0.0000 | 40.8352 | 0.0000 |

Table 2: Mole Fraction of Hydrocarbons (x_1), Refractive Index (n), Deviations in Refractive Index (Δn), Molar Refractions (R) and Deviations in Molar Refractions (ΔR) at 308.15 K for Various Samples of 3-Methylbutylethanoate + Hydrocarbons (x_1) System.

| S. No. | x_1 | n | Δn | $R \times 10^6$ ($m^3 mol^{-1}$) | $\Delta R \times 10^6$ ($m^3 mol^{-1}$) |
|---|---------|--------|------------|---------------------------------------|--|
| 3-Methylbutylethanoate (x_2) + Cyclohexane(x_1) | | | | | |
| 1. | 0.00000 | 1.3942 | 0.0000 | 36.3363 | 0.0000 |
| 2. | 0.09460 | 1.3958 | -0.0023 | 35.3181 | -0.5672 |
| 3. | 0.19949 | 1.3968 | -0.0025 | 34.6455 | -0.5147 |
| 4. | 0.29883 | 1.3982 | -0.0037 | 33.7795 | -0.7259 |
| 5. | 0.39868 | 1.3998 | -0.0046 | 32.9189 | -0.8742 |
| 6. | 0.49719 | 1.4018 | -0.0051 | 32.0806 | -0.9503 |
| 7. | 0.59291 | 1.4032 | -0.0062 | 31.1875 | -1.0469 |
| 8. | 0.69939 | 1.4064 | -0.0057 | 30.6608 | -0.5840 |
| 9. | 0.79318 | 1.4092 | -0.0053 | 29.4987 | -0.7973 |
| 10. | 0.89715 | 1.4140 | -0.0032 | 28.7118 | -0.4248 |
| 11. | 1.00000 | 1.4198 | 0.0000 | 27.8595 | 0.0000 |
| 3-Methylbutylethanoate(x_2) + Benzene(x_1) | | | | | |
| 1. | 0.00000 | 1.3942 | 0.0000 | 36.3363 | 0.0000 |
| 2. | 0.09627 | 1.4002 | -0.0034 | 35.3997 | -0.3319 |
| 3. | 0.19928 | 1.4062 | -0.0075 | 34.3266 | -0.7021 |
| 4. | 0.30001 | 1.4132 | -0.0104 | 33.3213 | -0.9510 |
| 5. | 0.39844 | 1.4200 | -0.0136 | 32.2892 | -1.1550 |
| 6. | 0.49437 | 1.4282 | -0.0145 | 31.3291 | -1.2863 |
| 7. | 0.59729 | 1.4384 | -0.0143 | 30.3209 | -1.2766 |
| 8. | 0.69545 | 1.4464 | -0.0160 | 29.1973 | -1.3212 |
| 9. | 0.79760 | 1.4622 | -0.0102 | 28.3640 | -0.6806 |
| 10. | 0.89807 | 1.4744 | -0.0078 | 27.2913 | -0.5822 |
| 11. | 1.00000 | 1.4922 | 0.0000 | 26.2723 | 0.0000 |

(Table 2). Continued.

| S. No. | x_1 | n | Δn | $R \times 10^6$ ($m^3 mol^{-1}$) | $\Delta R \times 10^6$ ($m^3 mol^{-1}$) |
|---|---------|--------|------------|---------------------------------------|--|
| 3-Methylbutylethanoate(x_2) + 1,4-Dimethylbenzene(x_1) | | | | | |
| 1. | 0.00000 | 1.3942 | 0.0000 | 36.3363 | 0.0000 |
| 2. | 0.90520 | 1.4018 | -0.0013 | 36.3416 | 0.0244 |
| 3. | 0.19034 | 1.4094 | -0.0027 | 36.3102 | 0.0130 |
| 4. | 0.25459 | 1.4184 | -0.0087 | 36.5906 | 0.3073 |
| 5. | 0.39408 | 1.4270 | -0.0128 | 36.2713 | 0.0192 |
| 6. | 0.48939 | 1.4354 | -0.1461 | 36.2243 | -0.0058 |
| 7. | 0.59486 | 1.4458 | -0.0043 | 36.2733 | 0.0694 |
| 8. | 0.69265 | 1.4554 | -0.0039 | 36.2292 | 0.0503 |
| 9. | 0.79706 | 1.4658 | -0.0033 | 36.1743 | 0.0232 |
| 10. | 0.90026 | 1.4768 | -0.0020 | 36.1184 | -0.0039 |
| 11. | 1.00000 | 1.4882 | 0.0000 | 36.0933 | 0.0000 |
| 3-Methylbutylethanoate (x_2)+ 1,3,5-Trimethylbenzene(x_1) | | | | | |
| 1. | 0.00000 | 1.3942 | 0.0000 | 36.3633 | 0.0000 |
| 2. | 0.09296 | 1.4028 | -0.0004 | 36.6298 | -0.1293 |
| 3. | 0.20015 | 1.4114 | -0.0002 | 37.2025 | 0.0219 |
| 4. | 0.29585 | 1.4202 | -0.0027 | 37.6596 | 0.0658 |
| 5. | 0.39366 | 1.4300 | -0.0028 | 38.1561 | 0.1205 |
| 6. | 0.48395 | 1.4392 | -0.0019 | 38.6033 | 0.1793 |
| 7. | 0.60501 | 1.4508 | -0.0021 | 39.1323 | 0.1606 |
| 8. | 0.70000 | 1.4602 | -0.0019 | 39.5970 | 0.1881 |
| 9. | 0.79930 | 1.4704 | -0.0013 | 40.0381 | 0.1648 |
| 10. | 0.90516 | 1.4822 | 0.0002 | 40.5593 | 0.1971 |
| 11. | 1.00000 | 1.4912 | 0.0000 | 40.8352 | 0.0000 |

experimental values of densities for liquids and their mixtures are used to evaluate

$$\Delta n = n - x_1 n_1 - x_2 n_2 \quad \dots 2$$

Where n and n_1 , n_2 are refractive indices of the mixtures and the components 1 and 2 are refractive indices of the mixtures and the components 1 and 2 respectively are also recorded in Tables 1 and 2.

Redlich-Kister equation [11] given below

$$\Delta n = x_1 x_2 [A + B (x_1 - x_2) + C (x_1 - x_2)^2] \quad \dots 3$$

Where A, B and C are the coefficients of the equation is generally used by the chemists to analyse thermodynamic data on liquid mixtures. However, Desnoyers and Perron [12] has suggested in agreement with the original statements of Redlich and

Kister, that plot of $Y^E / x_1(1-x_1)$ is better for this purpose. In the present investigation Redlich – Kister equation was fitted to the evaluated Δn values and the coefficients of equation and standard deviation σ (Δn) for all the systems are recorded in Tables (3-4).

Perusal of Tables 1 and 2 reveals that refractive indices for all the mixtures increases with mole fractions of hydrocarbons. It shows that the order of refractive index for binary mixtures of n-butylethanoate and 3-methylbutylethanoate with hydrocarbons is.

Cyclohexane < benzene < 1,4-dimethylbenzene < 1,3,5-trimethylbenzene

And this order is shown in Figures (3-4).

Variations of deviation in refractive indices, Δn for the mixtures studied with concentrations of

Table 3: Values of Constants A, B, C and Standard Deviations of Deviation in Refractive Index, σ (Δn) for Different Binary Systems at 308.15 K

| S. No. | System | A | B | C | σ (Δn) |
|--------|---|----------|---------|---------|-------------------------|
| 1. | 1-butylethanoate + Cyclohexane | - 0.1270 | 0.0638 | 0.3036 | ± 0.0221 |
| 2. | 1-butylethanoate + Benzene | - 0.1326 | 0.9916 | 2.5860 | ± 0.3819 |
| 3. | 1-butylethanoate + 1.4-dimethylbenzene | -0.0153 | 0.0093 | 2.0917 | ± 0.0799 |
| 4. | 1-butylethanoate + 1.3,5-trimethylbenzene | - 0.0093 | 0.0237 | -0.3751 | ± 0.0000 |
| 5. | 3-methylbutylethanoate + Cyclohexane | 1.5708 | 0.0043 | -0.7431 | ± 0.3528 |
| 6. | 3-methylbutylethanoate + Benzene | - 0.0335 | -0.1293 | -0.4993 | ± 0.0238 |
| 7. | 3-methylbutylethanoate +1.4-dimethylbenzene | -0.1805 | 0.1185 | -0.4605 | ± 0.0529 |
| 8. | 3-methylbutylethanoate + 1.3,5-trimethylbenzene | -0.0122 | 0.0211 | -0.3379 | ± 0.0153 |

Table 4: Values of Constants A, B and C and Standard Deviations of Deviation in Molar Refractions, σ (ΔR) for Different Binary Systems at 308.15 K

| S. No. | System | A | B | C | σ (ΔR) $\times 10^6$ ($m^3 mol^{-1}$) |
|--------|---|----------|---------|---------|--|
| 5. | 1-butylethanoate + Cyclohexane - | 1.2435 | 0.7582 | -0.6949 | ± 0.0824 |
| 6. | 1-butylethanoate + Benzene | -2.9082 | 1.5065 | 0.9920 | ± 0.1299 |
| 7. | 1-butylethanoate + 1.4-dimethylbenzene | -0.2647 | 0.7471 | 2.8855 | ± 0.1665 |
| 8. | 1-butylethanoate + 1.3,5-trimethylbenzene | 0.1039 | 0.2720 | 4.2809 | ± 0.5082 |
| 9. | 3-methylbutylethanoate + Cyclohexane | - 0.0973 | -0.0180 | 0.1265 | ± 0.8978 |
| 10. | 3-methylbutylethanoate + Benzene | - 5.0972 | -1.3610 | 0.0131 | ± 0.1298 |
| 11. | 3-methylbutylethanoate + 1.4-dimethylbenzene | 2.9459 | 1.2942 | -0.6813 | ± 0.6149 |
| 12. | 3-methylbutylethanoate + 1,3,5-trimethylbenzene | 0.9282 | 1.6671 | -1.3192 | ± 0.0962 |

hydrocarbons are shown in Figures (5-6). The Δn values are negative for all the binary mixtures of ester with all the hydrocarbons.

Experimental n values are used to evaluate molar refraction, R for all the binary mixtures studied by equation:

$$R = [x_1 M_1 + x_2 M_2 / \rho] [(n^2 - 1) / n^2 + 2] \quad \dots (4)$$

Where R is the molar refraction, x_1 and x_2 are mole fractions of components 1 and 2 M_1 and M_2 are the molecular weight of component 1 and 2, ρ is the density, n is the refractive index.

R values for all the mixtures also given in Tables 1 and 2 for both the systems with hydrocarbons variations of R with composition of mixtures are linear for all the binary mixtures. Values of R at equimolar compositions follow the trend similar that of Δn values as given above and shown in Figures 7 and 8.

Deviation in molar refraction from the linear blending rule (ΔR) have been defined on mole fraction basis [13,14]. Considering molar refraction as isomorphic to the molar volume. However, others [15,16] have defined it on volume fraction basis. In the present investigation ΔR has been evaluated on volume fraction basis as equation 5:

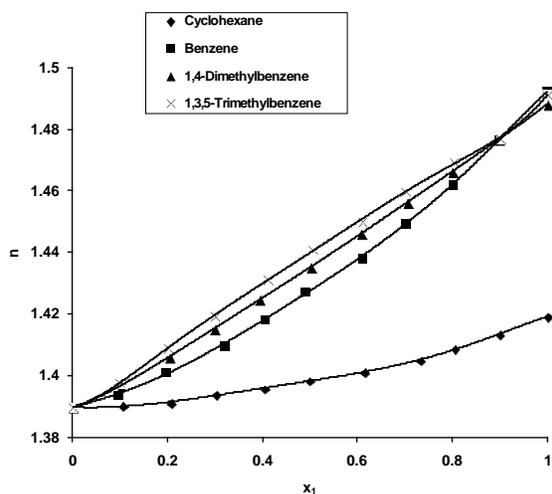


Figure 3: Refractive indices (n) for different binary systems of 1-butylethanoate + hydrocarbons versus mole fractions (x_1) of hydrocarbons at 308.15 K.

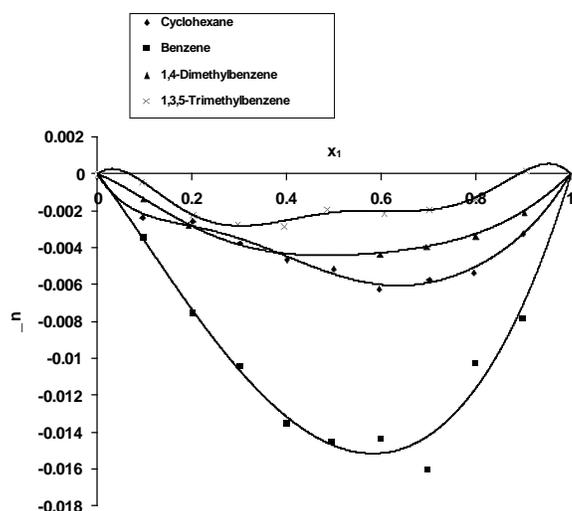


Figure 6: Deviations in refractive indices (n) for different binary systems of 3-methylbutylethanoate + hydrocarbons versus mole fractions (x_1) of hydrocarbons at 308.15 K.

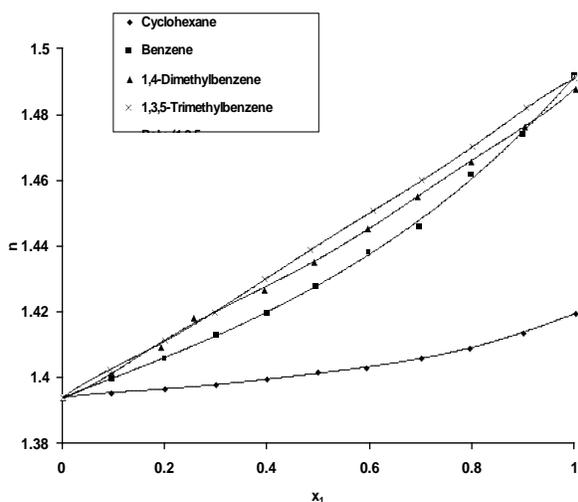


Figure 4: Refractive indices (n) for different binary systems of 3-methylbutylethanoate + hydrocarbons versus mole fractions (x_1) of hydrocarbons at 308.15 K.

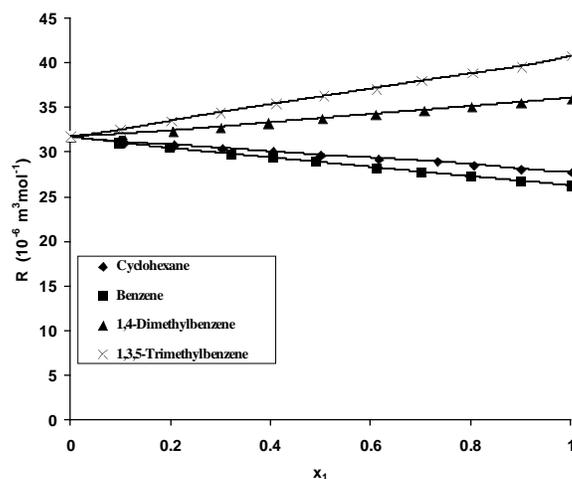


Figure 7: Molar refractions (R) for different binary systems of 1-butylethanoate + hydrocarbons versus mole fractions (x_1) of hydrocarbons at 308.15 K.

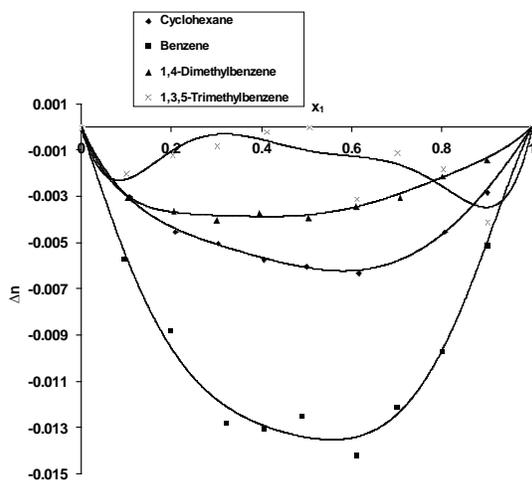


Figure 5: Deviations in Refractive indices (n) for different binary systems of 1-butylethanoate + hydrocarbons versus mole fractions (x_1) of hydrocarbons at 308.15 K.

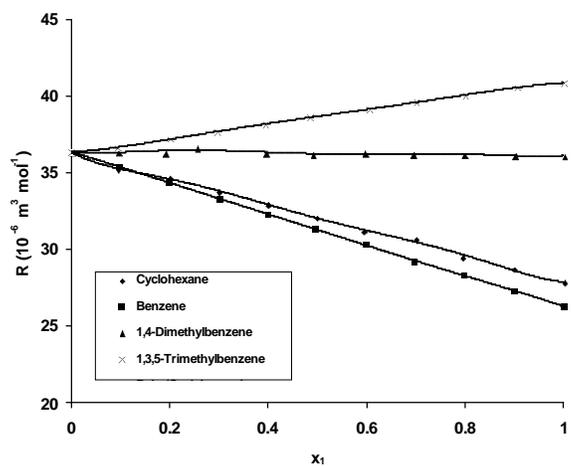


Figure 8: Molar refractions (R) for different binary systems of 3-methylbutylethanoate + hydrocarbons versus mole fractions (x_1) of hydrocarbons at 308.15 K.

$$\Delta R = R - \Phi_1 R_1 - \Phi_2 R_2 \quad \dots (5)$$

Where R_1 , R_2 are the molar refractions of pure components and Φ_1 and Φ_2 are their volume fractions in binary mixtures. The ΔR values with composition for all the systems at experimental temperature evaluated by equation (4) are recorded in Tables 1 and 2. Redlich–Kister equation was fitted to the ΔR values and the coefficients of the equation together with standard deviation σ (ΔR) for all the systems are recorded in Table 4. Variations of ΔR with composition for all the binary systems studied are shown in Figures 9 and 10.

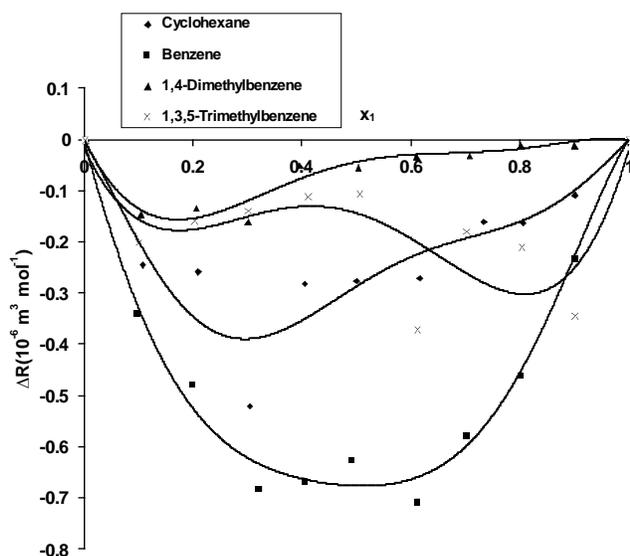


Figure 9: Deviations in Molar refractions (ΔR) for different binary systems of 1-butylethanoate + hydrocarbons versus mole fractions (x_1) of hydrocarbons at 308.15 K.

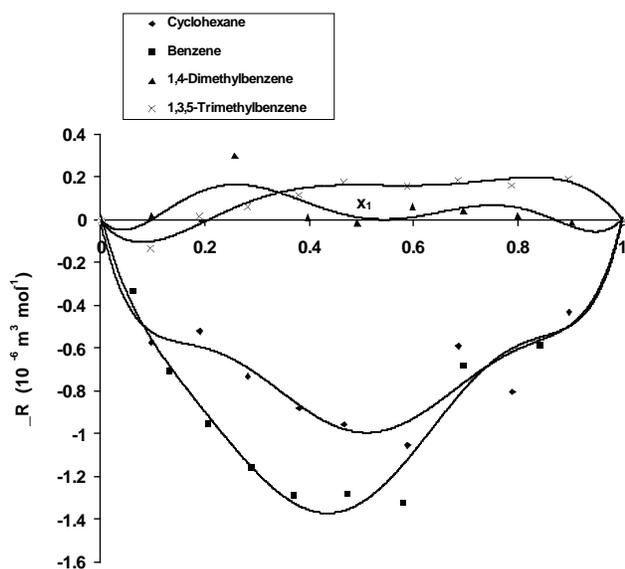


Figure 10: Deviations in molar refractions (ΔR) for different binary systems of 3-methylbutylethanoate + hydrocarbons versus mole fractions (x_1) of hydrocarbons at 308.15 K.

It is evident from Figures 5 and 6 that ΔR values are negative for binary systems of n-butylethanoate with all the hydrocarbons. But for the binary systems of 3-methylbutylethanoate ΔR values are negative for cyclohexane and benzene positive for 1,4-dimethylbenzene and 1,3,5-trimethylbenzene.

CONCLUSION

Refractive index and density of binary mixtures are useful for evaluation of molar refraction. These evaluations give information about molecular interactions between the components of the mixture.

ACKNOWLEDGEMENTS

The authors are thankful to the Head, Department of Chemistry, D.D.U. Gorakhpur University, Gorakhpur for providing laboratory facilities and to UGC New Delhi for financial assistance.

REFERENCES

- [1] Trenzado JL, Matos JS, Segade L, Carballo E. Densities, Viscosities, and related Properties of some (Methyl Ester + Alkane) Binary Mixtures in the Temperature Range from 283.15 to 313.15K. J Chem Eng Data 2001; 46: 974-83. <http://dx.doi.org/10.1021/je0100286>
- [2] Baragi JG, Aralaguppi MI, Aminabhavi TM. Density, Viscosity, Refractive Index, and Speed of Sound for Binary Mixtures of Anisole with 2-Chloroethanol, 1,4-Dioxane, Tetrachloroethylene, Tetrachloroethane, DMF, DMSO, and Diethyl Oxalate at (298.15, 303.15, and 308.15) K. J Chem Eng Data 2005; 50: 910-16. <http://dx.doi.org/10.1021/je049610v>
- [3] Diwedi A, Singh M. Densities, viscosities, viscosity deviations and excess thermodynamic properties of binary liquid mixtures of diethyl oxalate and dimethyl malonate with polar and non-polar solvents at 303.15 K. Indian J Chem 2007; 46A: 789-94.
- [4] Nikam PS, Kharat SJ. Density and Viscosity Studies of binary Mixtures of *N,N*-Dimethylformamide with Toluene and Methyl Benzoate at (298.15, 303.15, 308.15, and 313.15) K. J Chem Eng Data 2005; 50: 455-59. <http://dx.doi.org/10.1021/je040012g>
- [5] Lien PJ, Wu ST, Lee MJ, Lin HM. Excess Molar Enthalpies for Dimethyl Carbonate with *o*-Xylene, *m*-Xylene, *p*-Xylene, Ethylbenzene, or Ethyl Benzoate at 298.15 K and 10.2 MPa. J Chem Eng Data 2003; 48: 632-36. <http://dx.doi.org/10.1021/je020181f>
- [6] Lien PJ, Lin HM, Lee MJ, Venkatesu P. Excess molar enthalpies of diethyl carbonate with *o*-xylene, *m*-xylene, *p*-xylene, ethylbenzene, or ethyl benzoate at 298.15 K. Fluid Phase Equilib 2003; 206: 105-15. [http://dx.doi.org/10.1016/S0378-3812\(02\)00308-4](http://dx.doi.org/10.1016/S0378-3812(02)00308-4)
- [7] Garcia B, Alcalde R, Aparicio S, Leal JM. Thermophysical Behavior of Methylbenzoate + *n*-Alkanes Mixed Solvents. Application of Cubic Equations of State and Viscosity Models. Phys Chem Chem Phys 2002; 4: 5833-40.
- [8] Garcia B, Alcalde R, Aparicio S, Leal JM. Thermophysical Behavior of Methylbenzoate + *n*-Alkanes Mixed Solvents. Application of Cubic Equations of State and Viscosity Models. Ind Eng Chem Res 2002; 41: 4399-408. <http://dx.doi.org/10.1021/je020008c>

- [9] Lange NA. Hand Book of Chemistry. 10th ed., Mc. Graw – Hill Company, New York 1996.
- [10] Levitt BP. Findlay's Practical Chemistry. 9th ed., Longman Group Limited, London 1973.
- [11] Redlich O, Kister AT. Thermodynamics of Nonelectrolyte Solutions-x-y-t Relations in a Binary System. *Ind Eng Chem* 1948; 40: 341.
<http://dx.doi.org/10.1021/ie50458a035>
- [12] Desnoyers JE, Perron G. Treatment of excess thermodynamic quantities for liquid mixtures. *J Sol Chem* 1997; 26: 749.
<http://dx.doi.org/10.1007/BF02767781>
- [13] Tojo J, Diaz C. Densities and Refractive Indices for 1-Hexane + o-Xylene, m-Xylene,+ p-Xylene, and +Ethylbenzene. *J Chem Eng Data* 1995; 40: 96-98.
<http://dx.doi.org/10.1021/ie00017a021>
- [14] Marchetti AL, Tassi L, Ulrici A, Vaccari G, Sanna G. Refractive indices of binary mixtures of (1,2-dichloroethane + 2-chloroethanol) at various temperatures. *J Chem Thermodyn* 1999; 31: 647.
<http://dx.doi.org/10.1006/jcht.1998.0475>
- [15] Aralaguppi MI, Amniabhavi TM, Balundgi RH, Joshi SS. Thermodynamic interactions in mixtures of bromoform with hydrocarbons. *J Phys Chem* 1991; 5299.
<http://dx.doi.org/10.1021/j100166a070>
- [16] Amniabhavi TM, Aralaguppi MI, Harogoppad SB, Balundgi RH. Densities, viscosities, refractive indices, and speeds of sound for methyl acetoacetate + aliphatic alcohols (C1-C8). *J Chem Eng Data* 1993; 38: 31.
<http://dx.doi.org/10.1021/je00009a008>

Received on 02-11-2012

Accepted on 13-02-2013

Published on 28-02-2013

[DOI: http://dx.doi.org/10.6000/1929-5030.2013.02.01.8](http://dx.doi.org/10.6000/1929-5030.2013.02.01.8)